

Original Research Article

Biochemical properties and Air Pollution Tolerance Indices of Plants in Port Harcourt City, Nigeria

ABSTRACT

Aims: The impact of air pollution on biochemical properties and air pollution tolerance indices of ten plants growing at Trans-Amadi Industrial Lay-out and along East-West Road, Port Harcourt alongside Umuokiri-Aluu as control site were studied.

Study design: The leaves of the plants were collected and used to determine fresh weight, turgid weight, dry weight, relative water content, leaf extract pH, ascorbic acid content and total chlorophyll content. Air pollution tolerance indices were calculated from data obtained for each plant species.

Results: Results showed that relative water content of leaf samples were of the order Trans-Amadi Industrial Lay-out > East-West Road compared with the control. Leaf extract pH was higher at Trans-Amadi Industrial Lay-out and East-West Road than the control while Ascorbic acid was lower at Trans-Amadi and East-West Road. Percentage increase in air pollution tolerance index of seven plants of Trans-Amadi followed the order: *Terminalia catappa* (7.70 %), *Eluesine indica* (22.24 %), *Musa sapientum* (25.54 %), *Panicum maximum* (26.56 %), *Psidium guajava* (37.10 %), *Mangifera indica* (44.18 %), *Delonix regia* (181.90 %) while that of East-West Road were of the order: *Musa paradisiaca* (4.84 %), *Chromolaena odorata* (13.19 %), *Panicum maximum* (20.17 %), *Musa sapientum* (23.95 %), *Carica papaya* (25.04 %), *Psidium guajava* (25.32 %), *Mangifera indica* (33.63 %).

Conclusion: Air pollution tolerance indices of the plants were of the sensitive category and hence they can be used to monitor air quality of Niger Delta.

Keywords: air pollution, biochemical properties, Port Harcourt, pollution tolerance.

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INTRODUCTION

Air pollution which can simply be defined as the alteration of the natural composition of the atmosphere especially due to human activities is one of the severe problems the world is facing today (Tripathi & Gautam, 2007). This condition results out of some anthropogenic activities such as urbanization, industrialization, vehicular exhaust gas emissions, power generation and some domestic activities. These processes release particulate matter, radioactive materials and gases such as carbon monoxide (CO), carbon dioxide (CO₂), sulphur dioxide (SO₂), nitrogen oxide (NO), hydrogen sulphide (H₂S), hydrogen chloride (HCl) and ammonia (NH₃) into the atmosphere and therefore give rise to pollution. The presence and at certain concentrations of these substances in the atmosphere deteriorates air quality.

Air pollution directly affects plants through direct uptake of pollutants from it by the leaves as respiratory organs or indirectly from soil acidification through root absorption. Most plants experience physiological changes before exhibiting visible damage on their leaves when exposed to air pollutants (Liu and Ding, 2008; Dohmen *et al.*, 1990). Some visible signs of air pollution impacts on plants include bleached spots, chlorosis, necrotic spots, lesions, premature senescence, reduced growth and yield in sensitive plant species (Narayanan, 2006; Tiwari *et al.*, 2006; Kuddus *et al.*, 2011). Although, vegetation which serves as sink of air pollutants is an effective indicator of overall impact of air pollution have long been used as biomonitors of air pollution (Joshi and Swami, 2007). The effects of air pollution on plants are time-averaged results that are more reliable than those obtained from direct determination of pollutants in air over a short period. This is because plants provide an enormous leaf area for impingement, absorption and accumulation of air pollutants and so they reduce the pollution level in air (Liu and Ding, 2008). This capability varies to some extents in different plant species. The use of Ascorbic acid content (Hoque, *et al.*, 2007), chlorophyll content (Flowers *et al.*, 2007), leaf

extract pH (Klumpp *et al.*, 2000) and relative water content (Rao, 1979) have been used to determine the sensitivity and tolerance of plants to air pollution. Singh and Rao (1983) classified Air Pollution Tolerance Indices (APTI) value of plants as follows:

Categories of plants based on APTI

S/No	APTI value	Class
1	>17	Tolerant
2	>10 and <16	Intermediate
3	< 10	Sensitive

In Niger Delta of Nigeria, air pollution has been on the increase since the commencement of oil and gas exploration in the region. The underlying factors responsible for air pollution in the area are industrialization and a general high rate of urbanization (Hicks, 1998). Ana (2011) highlighted gas flaring, refinery, petrochemical and fertilizer plants gaseous effluents emission into atmosphere, burning of fossil fuels and oil facilities fires as some sources of air pollution in the area. In addition to the above sources, agricultural practice (bush burning), refuse burning and automobile emission are other sources of air pollution in the area. With all the above sources still operational in the area, there is no question about air pollution in the area. However, no major attempt has been undertaken to assess atmospheric pollution tolerance indices of plants in Port Harcourt metropolis. Hence, this research work has its thrust on the study of air pollution tolerance indices of plants growing in the city.

MATERIALS AND METHODS

Study Area

This study was carried out in Port Harcourt, the capital city of Rivers State. Port-Harcourt is located between latitudes 4° 43' - 4° 54' N and longitudes 6° 56' - 7° 03' E. The city lies along the Bonny River in the Niger Delta of southern Nigeria. The city covers an area of 186 km²: 170 km²

land and 16 km² Water (<http://en.wikipedia.org/wiki/Port-Harcourt>). The population of Port-Harcourt is estimated at 1,620,214 in the year 2007 (<http://en.wikipedia.org/wiki/PortHarcourt>). The main industrial area of the city is the Trans-Amadi Industrial Lay-out.

Port Harcourt features a tropical climate with lengthy and heavy rainy season and very short dry season. Temperature throughout the year in the city is relatively constant with mean annual temperature of about 29 °C (<http://en.wikipedia.org/wiki/PortHarcourt>). It has double maxima rainfall peaks with first peak usually around June/July and the second in September before the onset of dry season (Oyegun and Ologunorisa, 2002). Mean annual rainfall of the city is over 2000 mm. The heaviest precipitation in the city occurs during September with an average of 370 mm. Only the months of December and January are the actual dry season months of the city. Harmattan which climatically influences many cities in the middle belt and northern Nigeria is less experienced in Port Harcourt.

Sampling locations

Specifically, this study was carried out at three locations: Trans-Amadi Industrial Layout, East-West Road (Kilometre 10 -16) and Umuokiri, Aluu (Fig. 1). Trans-Amadi Industrial Lay-out is at the heart of the city of Port Harcourt. It host many industries and also in proximity with Eleme, another industrial axis in boundary with Port Harcourt. Trans-Amadi is an area of high atmospheric pollution and wastes generation due to the various industrial operations undertaken by the different manufacturing companies in the area. For the purpose of this study, this area was taken as study site 1 (SS 1). Kilometre 10-16 of the East-West Road (which is a component of the trunk road of the the East-West Road that links Rivers State with Bayelsa and Akwa Ibom States) experiences high vehicular traffic. This second site was taken as study site 2 (SS 2) while Omuokiri, Aluu which is about 27.7 km away from Port Harcourt city is free from high vehicular

rainfall in the region. The leaves of same plant species from same study location were bulked together to form composite sample which were used for analysis.

Leaf relative water content (RWC) was obtained through the method and formula of Singh (1977). The fresh leaf samples were immediately weighed by means of digital balance (satorius II 623S) on arrival at laboratory. The samples after fresh weight measurement were placed in water for 24 hours, blotted dry with absorbent paper and reweighed to obtain turgid weight. The turgid leaves were dried in oven (Gallenkamp model) for seven days at 78⁰ C to dry and weighed to obtain dry weight. Leaf relative water content was then calculated using the relationship:

$$RWC = \frac{FW - DW}{TW - DW} \times 100$$

Where FW = fresh weight

DW = dry weight

TW = turgid weight

Leaf total chlorophyll content (LT_{chl}) was determined by weighing 0.1 g of each leaf sample soaked in 20 ml of 50% acetone and allowed for five (5) days interval to form solution whose absorbance was taken at 645 nm and 660 nm using spectrophotometer(Stewart *et al.* 1974).

Leaf total chlorophyll content, LT_{chl} (mg/l) =

$$\frac{7.12 \times \text{optical density at 660 nm} + 16.8 \times \text{optical density at 645 nm}}{10}$$

Leaf extract pH (L_{pH}) was determined by weighing and blending to powder 10 g of fresh leaf sample then homogenizing in 20 ml of deionized water. The mixture was filtered and pH of the filtrate taken after calibrating pH meter (Jennway 3015) with buffer solutions of pH 3 and 9 while leaf ascorbic acid content, L_{aa} (mg/g) content was measured using indophenol acetic acid (IAA) method by weighing and crushing 0.1 g of fresh leaf sample. The crushed leaf was

homogenized in a mixture of 50 ml distilled water and 10 ml acetic acid. The resulting mixture was titrated against 0.01% indophenol solution. Air pollution tolerance index (APTI) was calculated using the formula of Singh and Rao (1983).

$$APTI = \frac{A(T+P) + R}{10}$$

Where in the formula A = ascorbic acid content (mg/g)

T= total chlorophyll (mg/g)

P = pH of leaf extract

R= leaf relative water content (%)

The results obtained were presented in vertical bar charts using Microsoft office Excel package 2007 version. Percentage increase in air pollution tolerance indices of the plants from the sites was also calculated using the formula:

$$\% \text{increase} = \frac{APTI(SS) - APTI(CS)}{APTI(CS)} \times \frac{100}{1}$$

Results and Discussion

The results of the impact of air pollution on plant biochemical were presented in Figs 2 – 8. Fresh, turgid and dry weights results were presented in Figs. 2-4 below. *M. paradiasica* and *C. papaya* showed a higher leaf fresh weight and turgid weight in the control site than at the study site (Figs. 2 and 3) while no significant differences were found in the leaf dry weight of plants between the study sites and their respective controls (Fig. 4). Relative water contents, RWC (%) of leaf samples from the study sites (SS 1 and 2) were generally higher than those from the control site (CS) (Fig. 5). Relative water content of study site 1 (SS 1) ranged between 57.6 - 89.9 % with a mean of 73. 55 % while that of study site 2 (SS 2) ranged between 65.3 - 79.9 % with 63.68 % as its mean. The highest RWC of 89.9 % recorded for *Mangifera indica* at SS 1 and the least 17.3 % for *Delonix regia* from the control site. This result suggests that plants of the

study sites absorbed and retained more water than the ones of control site. Higher RWC result of plants of polluted sites is in line with Kousar *et al.* (2014). This could be a physiological adaptive mechanism of the plants to withstand the effect of atmospheric pollution in its environment.

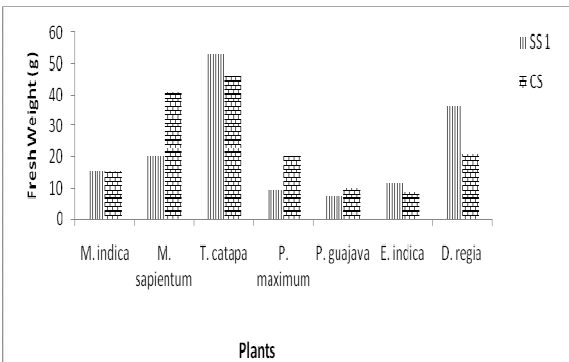


Fig. 2a: leaf fresh weight of plants in site 1

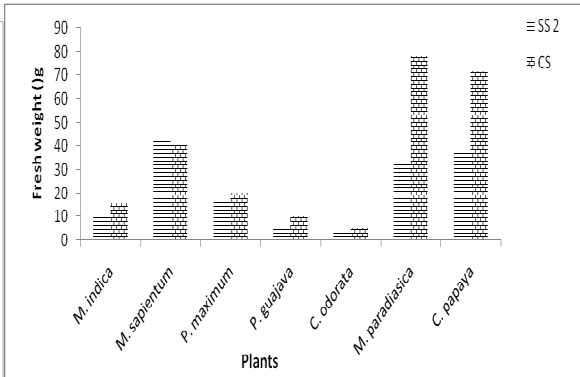


Fig. 2b: leaf fresh weight of plants in site 2

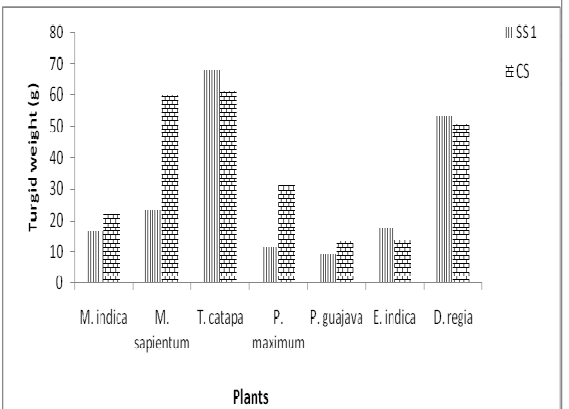


Fig. 3a: leaf turgid weight of plants in site 1

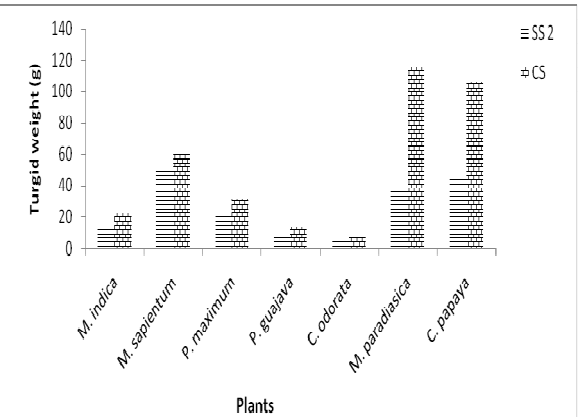


Fig. 3b: leaf turgid weight of plants in site 2

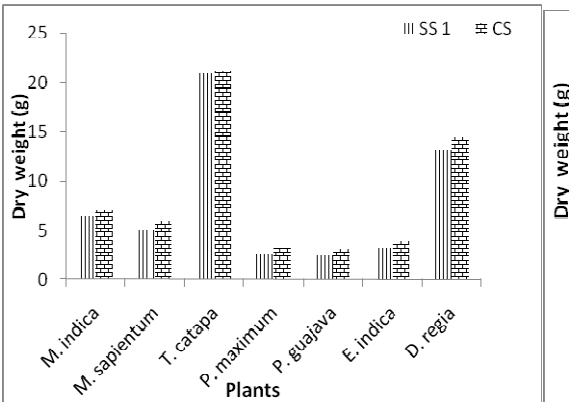


Fig. 4a: leaf dry weight of plants in site 1

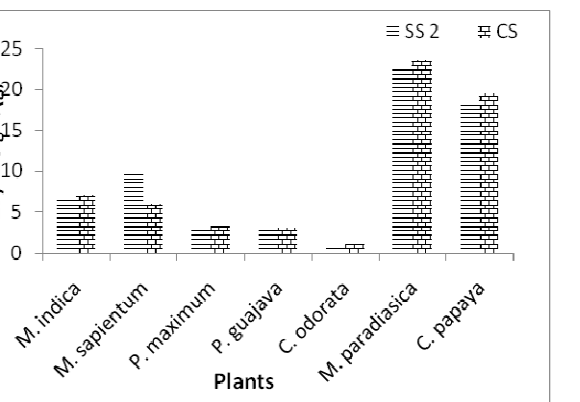


Fig. 4b: leaf dry weight of plants in site 2

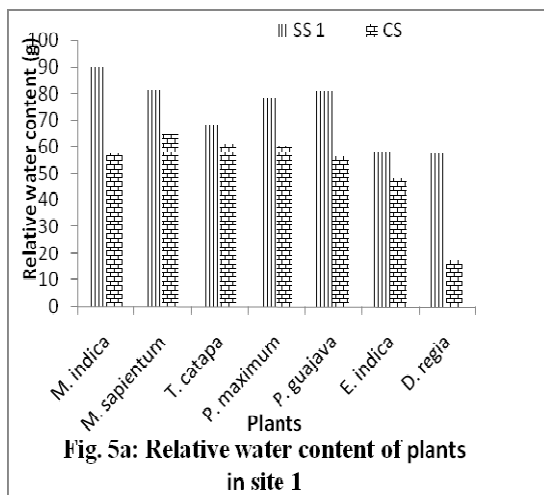


Fig. 5a: Relative water content of plants in site 1

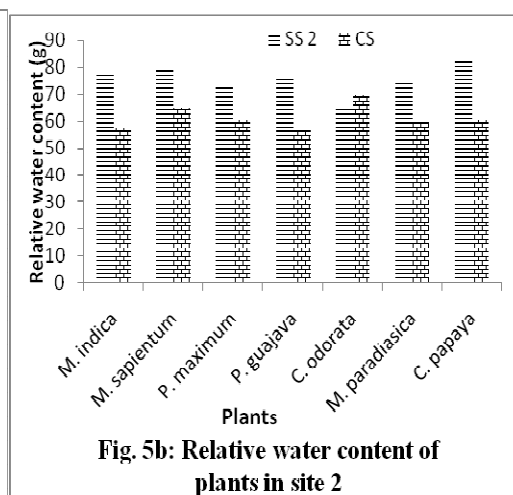


Fig. 5b: Relative water content of plants in site 2

Leaf extract pH of study sites leaf samples were higher than those from control site (Figs 6). The highest recorded pH was 6.83 on *Carica papaya* study site 2 (Fig. 6b) and the least (4.08) was obtained on *Musa sapientum* (Fig. 6a). This result follows the trend of RWC in which the plants at the study sites have high RWC than the control site. This could be explained to be due to the higher amount of water absorbed and retained by plants of the study sites. The high amount of water could have diluted the chemical effect of air pollutants in order to maintain optimum physiological pH for metabolism (Dedio, 1975). Ascorbic acid as a natural detoxicant help prevent the damaging effects of air pollutants on plant tissues (Singh *et al.*, 1991) and so high amount of the substance favours air pollution tolerance. Ascorbic acid content (AAC) was found to occur at low level in the plant samples of the study sites compared with the control site (Figs. 7). Keller and Schwager (1977) observed that air pollution decreases the ascorbic acid level in plant. Leaf chlorophyll content did not show any consistent pattern in both study sites and control sites (Fig. 8).

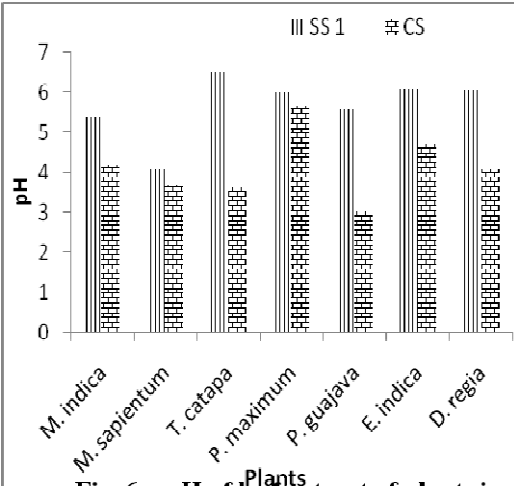


Fig. 6a: pH of leaf extract of plants in site 1

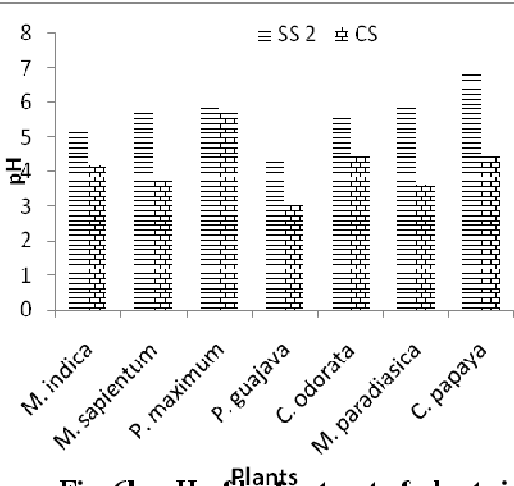


Fig. 6b: pH of leaf extract of plants in site 2

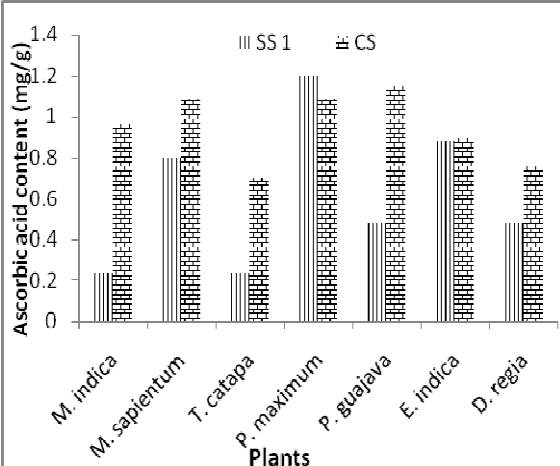


Fig. 7a: Ascorbic acid contents plant leaves of site 1

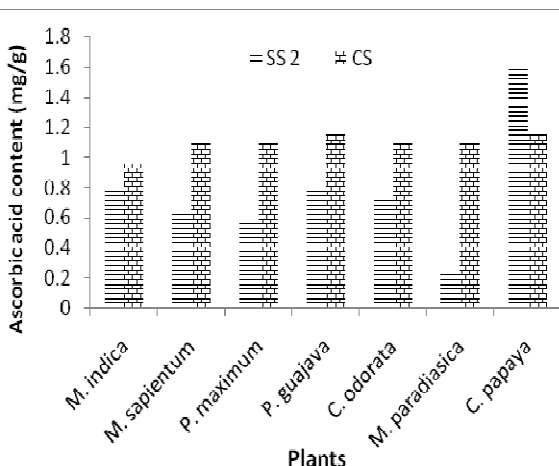
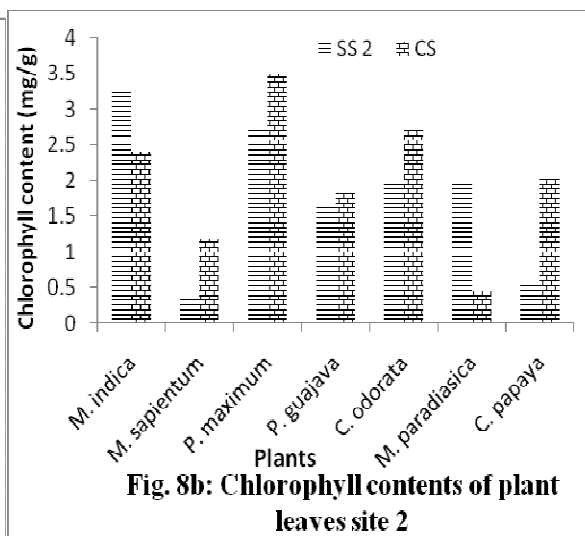
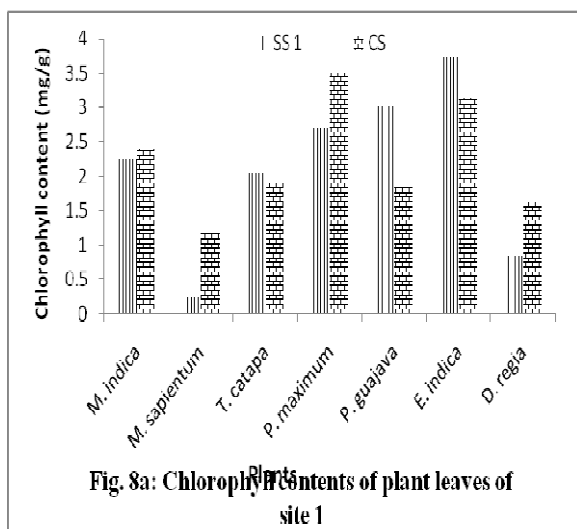


Fig. 7b: Ascorbic acid contents plant leaves of site 2



Generally, computed APTI values showed that all plant samples had APTI values < 10 (i.e. APTI sensitive category). Values of the study sites samples were higher than those of the control site (Table 1). APTI values of 9.17 (*M. indica*), 8.70 (*M. sapientum*), 8.50 (*P. guajava*) and 8.19 (*P. maximum*) of study site 1 were higher than those of same species of site 2. The highest and least values (i.e. 9.17 and 6.09) were obtained for *M. indica* and *D. regia* respectively from study site 1 while 8.59 and 6.72 for *M. sapientum* and *M. paradisiaca* of site 2.

Table 1: summary of APTI results

Plant sample	APTI (control site)	APTI (study site 1)	% Increase in APTI (study site 1)	APTI (study site 2)	% Increase in APTI (study site 2)
<i>Mangifera indica</i>	6.36	9.17	44.18	8.50	33.65
<i>Musa sapientum</i>	6.93	8.70	25.54	8.59	23.95
<i>Terminalia catappa</i>	6.49	6.99	7.70	-	-
<i>Panicum maximum</i>	7.04	8.91	26.56	8.46	25.32
<i>Psidium guajava</i>	5.44	8.50	37.10	7.77	20.17
<i>Eluesine indica</i>	2.16	6.65	22.24	-	-
<i>Delonix regia</i>	2.16	6.09	181.90	-	-
<i>Musa paradisiaca</i>	6.41	-	-	6.72	4.84

<i>Chromolaena odorata</i>	7.84	-	-	8.11	13.19
<i>Carica papaya</i>	6.79	-	-	8.49	25.04

Comparing APTI results with findings of studies of other locations in Niger Delta, the highest percentage (181.90 %) change in APTI was obtained at study site 1 on *Delonix regia*. Other significant changes were 45.11% on *M. sapientum* at Utorogun, Delta State (Agbaire and Esiefarienrhe, 2009) and 44.18 % on *M. indica* at study site 1 (Table 2). The least change values were 0.10 % and 0.54 % on *P. guajava* at Umuebulu, Rivers State (Tanee and Albert, 2013) and Erhoike-Kokori, Delta State (Agbaire, 2009) respectively.

Table 2: comparison of APTI results from other locations in Niger Delta, Nigeria

Plant sample	Percentage (%) increase in APTI				
	Study site 1	Study site 2	Erhoike-Kokori	Otorogun	Umuebulu
<i>Mangifera indica</i>	44.18	33.65	43.79		
<i>Musa sapientum</i>	24.54	23.95		45.11	
<i>Terminalia catappa</i>	7.7		14.02		
<i>Panicum maximum</i>	26.56	25.32			
<i>Psidium guajava</i>	37.10	20.17	0.54		0.1
<i>Eleusine indica</i>	22.24				
<i>Delonix regia</i>	181.90		39.37		
<i>Musa paradisiaca</i>		4.84	6.59		6.8
<i>Chromolaena odorata</i>		13.19	39.37		

Conclusion

Based on the results of this study, it can be stated that air pollution tolerance index obtained using the four leaf biochemical status can serve in predicting air quality condition of an area. These biochemical parameters are important in the study of plant-environment interactions as

they can serve as bioindicators of air pollution. From this study, it can also be stated that plants such as *Mangifera indica*, *Musa sapientum*, *Musa paradisiaca*, *Terminalia catappa*, *Panicum maximum*, *Psidium guajava*, *Eluisea indica*, *Delonix regia*, *Chromolaena odorata* and *Carica papaya* with APTI values less 10 (APTI sensitive) can be used to monitor air quality of Niger Delta where these plants grow naturally considering air pollution activities going on in the area. The results of this and similar studies will be useful for air pollution monitoring, control measures and future planning.

References

- Agbaire, P. O. (2009). Air pollution tolerance indices (APTI) of some plants around Erhoike-Kokori oil exploration site of Delta State, Nigeria. *Int. J. Phys. Sci.* 4 (6): 366-368.
- Agbaire, P.O. and Esiefarienrhe, E. (2009). Air Pollution tolerance indices (APTI) of some plants around Otorogun Gas Plant in Delta State, Nigeria. *J. Appl. Sci. Environ. Manage.* 13(1): 11 – 14.
- Ana, G.R. (2011). Air Pollution in the Niger Delta Area: Scope, Challenges and Remedies, The Impact of Air Pollution on Health, Economy, Environment and Agricultural Sources. M. Khallaf (Ed.), ISBN: 978-953-307-528-0, InTech, Available from: <http://www.intechopen.com/books/the-impact-of-airpollution-on-health-economy-environment-and-agricultural-sources/air-pollution-in-the-niger-delta-area-scopechallenges-and-remedies>.
- Dedio, W. (1975). Water Relations in wheat leaves as Screening Test for Drought Resistance. *Can. J. Plant Sci.* 55, 369-378.
- Dohmen, G.P., Loppers, A., Langebartels, C., (1990). Biochemical Response of Norway Spruce (*Picea abies* (L.) Karst) toward 14-Month Exposure to Ozone and Acid mist, effect on amino acid, Glutathione and Polyamine Titrers. *Environ. Poll.* 64:375- 383.

232 Flowers, M. D., Fiscus, E.L., Burkey K.O., 2007. Photosynthesis, chlorophyll fluorescence and
 233 yield of snap bean (*Phaseolus Vulgaris* L) genotypes differing in sensitivity to Ozone.
 234 *Environmental and Experimental Botany* 61:190- 198.

235 Hicks, F.J. (1998). Enhancing the productivity of urban Africa. International Conference on
 236 Research Community for the Habitat Agenda Forum of Researchers on Human
 237 Settlements. Geneva., July 6-8, 1998. Online.
 238 <http://wbln0018.worldbank.org:80/External>
 239 /Urban/UrbanDev.nsf/Urban+Development/06FCBF7D26772E6885256B18007BA532?
 240 OpenDocument.
 241 <http://en.wikipedia.org/wiki/PortHarcourt>

242 Hoque, M.A., Banu, M.N.A., Oluma, E. (2007). Exogenous proline and glycinebetaine increase
 243 NaCl-induced Ascorbate glythione cycle enzyme activities and praline improves salt
 244 tolerance more than glycinebetaine in tobacco bright yellow-2 suspension-cultural cells.
 245 *J. plant physiol.* 164: 1457-1468.

246 Joshi ,P. C. and Swami, A (2007). Physiological responses of some tree species under roadside
 247 automobile pollution stress around city of Haridwar, India. *Environmentalist* 27:365–374.

248 Keller, T. and Schwager, H., (1977). Air pollution and ascorbic acid. *Eur. J. Forestry Pathol.* 7:
 249 338-350.

250 Klump, G., Furlan, C.M., Domingos, M., 2000. Response of stress indicators and growth
 251 parameters of *Tibouchina pulchra* Cogn exposed to air and soil pollution near the
 252 industrial complex of Cubatao, Brazil. *Scie. of Tot. Environ.* 246:79-91.
 253

254 Kousar, H., Nuthan, K. D., Pavithra, K and Adamsab. M. P. (2014). Analysis of Biochemical
 255 Parameters as Tolerance Index of Some Chosen Plant Species of Bhadravathi Town. *Int'l*
 256 *J. Environ. Sci.* 3 (1): 11-16.
 257

258 Liu, Y. J., Ding, H. (2008). Variation in air pollution tolerance index of plants near a steel
 259 factory: implication for landscape –plant species, selection for industrial areas. *Wseas*
 260 *Trans. Environ. Dev.* 4:24-32.

261 Narayanan, P. (2006). *Environmental Pollution: Principles, Analysis and Control*. CBS
 262 Publishers & Distributors, New Delhi.

263 Oyegun C.U. and Ologunorisa Y.E. (2002). Weather and Climate. In: *The land and people of*
 264 *Rivers State Eastern Niger Delta* E.J. Alagoa and A.A. Derefaka eds. Pp. 53-62.

265 Singare, P. U. and Talpade, M. S. (2013). Physiological Responses of Some Plant Species as a
 266 Bio-Indicator of Roadside Automobile Pollution Stress Using the Air Pollution Tolerance
 267 Index Approach. *International Journal of Plant Research*, 3(2): 9-16.

268 Stewarte, E.A., Grimshaw, H.M., Parkinson, J.A. and Quarmby, C. (1974). *Chemical Analysis of*
 269 *Ecological Materials*. Blackwell Publications, London.

270 Rao, D. N. (1979). Plant leaf as pollution monitoring device. *Fertilizer News*, 24, 25-28.

271 Singh, A. (1977): *Practical Plant Physiology*. Kalyari Publishers, New Delhi.

272 Singh, S. K. and Rao, D. N. (1983). Evaluation of plants for their tolerance to air pollution. *Proc.*
 273 *Symp on Air Pollution Control* held at IIT, Delhi. pp. 218-224.

274 Singh, S.K., Rao, D.N., Agrawal, M., Pandey, J., Narayan, D. (1991). Air Pollution Tolerance
 275 index of plants. *Journal of Environmental Management* 32: 45-55.

276 Tanee, F. B. G. and Albert, E. (2013). Air pollution tolerance indices of plants growing around
 277 Umuebulu Gas Flare Station in Rivers State, Nigeria. *Afr. J. Environ Sci. & Tech.* 7(1):
 278 1-8.

279 Tiwari, S., Agrawal, M., Marshall, F. M. (2006). Evaluation of ambient air pollution impact on
 280 carrot plants at a sub urban site using open top Chambers. *Environ. Monit. Assess.*
 281 119:15-30.

282 Tripathi, A. K. and Gautam, M. (2007). Biochemical parameters of plants as indicators of air
 283 pollution. *J. Environ. Bio.* 28(1):127-132.